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EVALUATION OF SAFETY AT RAILROAD-HIGHWAY GRADE CROSSINGS

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INTRODUCTION

The motor vehicle-train accident, though infrequent, is the most severe in terms of fatalities, personal injuries and property damage per accident of all types experienced on American highways. This type of accident, however, can be eliminated only by closing all crossings to highway traffic or by constructing grade separations for all rail-highway crossings. The delay and congestion resulting from the first alternative obviously would not be tolerated by the motoring public. Based on an estimated cost of separation improvements in Ohio, it would cost \$5 billion to construct grade separations at the 10,800 grade crossings in the State of Indiana. (4)*

Another alternative is to install modern flashing lights with short-arm gates at all crossings. Such an undertaking is estimated to reduce the number of accidents by a considerable amount, but the cost would be in excess of \$150 million. (4) This figure is more realistic but still represents an enormous sum of money. Furthermore, the expenditure of this amount of money might well be more efficiently used for the prevention of other types of accidents.

During 1962 and 1963, 149 people were killed in motor vehicle-train accidents in Indiana. This figure accounts for 6.0 percent of the total highway fatalities but only 0.4 percent of the total number of accidents. (1) The severity of these accidents is of general concern to the public and is invariably well publicized.

*Numbers in parentheses refer to sources listed in the Bibliography.



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The national trend for rail-highway grade crossing accidents is decreasing, but the reverse is true in Indiana. Based on data compiled by the Interstate Commerce Commission at the close of 1953, the numbers of grade crossing accidents and fatalities in Indiana were among the highest in the nation. Indiana was exceeded only by the State of Arkansas in grade crossing accidents per million cars registered and grade crossing deaths per million cars registered. (4)

The present warrants as specified by the Indiana State Highway Commission for the protection of highway-rail grade crossings are as follows:

- a) "Two or more main line tracks should be protected by flashing lights and short-arm gates;
- b) Where train speeds are 70 mph or greater on single line tracks, flashing lights and short-arm gates should be used; and
- c) All other crossings are protected by flashing lights except those where there is good sight distance in all quadrants and where either the highway traffic is less than 500 vehicles per day (ADT), or rail traffic less than 6 trains per day (TPD).

These latter crossings are protected by reflectorized crossbucks and advance warning signs." (3)

These general warrants do not result in priority ratings based on hazard. The priority for improving crossing protection at rail-highway intersections is left to subjective judgment.

In a recent report by the Interstate Commerce Commission based on data submitted by the railroads, Henry Winskey concluded that the major cause of rail-highway grade crossing accidents is the failure of motor-vehicle drivers to yield to trains. (2) The purpose of this research

study was to investigate existing conditions which might have encouraged drivers not to take reasonable precautions. This study constitutes an analysis of highway-rail grade crossing accidents with respect to the effects of environment, crossing geometry, highway and rail traffic patterns, existing protective devices, and other relevant elements and their relative importance as a basis for determining a more effective and economic means of establishing the necessary railroad crossing protection. (5)

PROCEDURE

Because accident data were readily available for only two years, 1962 and 1963, and so that more meaningful correlations could be developed, accident locations were compared to non-accident locations. The 289 accident locations, which included most of the rural crossings in Indiana with at least one accident in 1962 and 1963, were established by using the traffic accident reports of the Indiana State Police. The 241 non-accident locations were randomly selected throughout the State in proportion to the railroad mileage in each county.

The information for the study variables came primarily from three separate sources: police accident reports; field investigations; and railroad correspondence. A total of 28 variables was considered in evaluating the effects of environment, topography, geometry, and highway and railroad traffic patterns on the safety of rail-highway grade crossings in rural areas. Only those variables which significantly influenced the hazard of grade crossings are presented in the Results section.

Multiple linear regression analysis was performed on the 28 variables common to both accident and non-accident locations. The dependent variable was accident occurrence, a dichotomous variable representing occurrence or non-occurrence of an accident. The "buildup" regression routine allowed the ordering of the independent variables to permit the initial inclusion of preselected variables. For all equations, train and highway traffic volumes were ordered to permit their inclusion in the multiple regression expressions.

RESULTS

In an attempt to gain an insight into the characteristics of railroad-highway grade crossing accidents, the following statistical summary was developed from the accident locations analyzed in this research investigation.

1. Driver characteristics.

- a. Driver age - the average age of all drivers involved in a grade crossing accident was 36 years.
- b. Driver sex - 86 percent of these drivers were male.
- c. Driver residence - 72 percent of the drivers were from the county in which the accident occurred. Ninety-four percent of the drivers were residents of the State of Indiana.
- d. Number of occupants - the average number of occupants in accident vehicles was 1.36 persons per vehicle.
- e. Drinking driver - only six percent of the accident reports indicated that the driver had been drinking.
- f. Personal injury - 62 percent of the accidents resulted in at least one personal injury.
- g. Fatality - 14 percent of the accidents resulted in at least one fatality.

2. Vehicle characteristics.

- a. Vehicle type - 27 percent of the accident vehicles were trucks.
- b. Age of vehicle - the average age of vehicles involved in grade crossing accidents was 5.2 years.

- c. Vehicle defects - 17 percent of the accident vehicles evidenced contributing mechanical defects.
 - d. Window position - 71 percent of the vehicles were considered to have had their windows rolled up at the time of the accident.
 - e. Actual car speed - the average of the reported car speeds of vehicles involved in accidents was 24 mph.
 - f. Actual train speed - the average of the reported speeds of trains involved in accidents was 41 mph.
3. Environmental characteristics.
- a. Clear weather - 74 percent of the accidents occurred during clear weather.
 - b. Darkness - 36 percent of the accidents occurred at night.
 - c. Pavement surface moisture - pavements were dry 57 percent, wet 16 percent, and had ice or snow 27 percent of the time that accidents occurred.
 - d. Day of the week - accident occurrence by day of the week is summarized below:
- | | |
|-----------|-------|
| Monday | 14.2% |
| Tuesday | 14.5% |
| Wednesday | 11.3% |
| Thursday | 15.6% |
| Friday | 16.3% |
| Saturday | 15.6% |
| Sunday | 11.3% |

An equation was developed to account for the various protection devices, train and highway volumes and those additional variables which significantly influenced accident occurrence. This analysis produced the following prediction equation:

$$1. \quad IH = +0.149 - 0.376X_{29} - 0.300X_{30} - 0.383X_{31} - 0.331X_{32} + 0.082X_{40} \\ + 0.0223X_{41} + 0.011X_{54} + 0.0142X_{55} + 0.024X_{57}$$

where IH = index of hazard (accident occurrence),

X_{29} = presence of a painted crossbuck (0, 1),

X_{30} = presence of a reflectorized crossbuck (0, 1),

X_{31} = presence of a flasher (0, 1),

X_{32} = presence of a gate (0, 1),

X_{40} = number of track pairs,

X_{41} = pavement width in feet,

X_{54} = TPD,

X_{55} = ADT/1000, and

X_{57} = sum of distractions.

In addition to the protection variables, Equation 1 also includes variables which are measures of train and highway volumes. The type of rail and highway operations is represented by the variables designated as number of track pairs and pavement width. The number of roadside distractions which is the sum of the houses, businesses, and advertising signs per one-half mile on both sides of the roadway for one approach to the crossing, proved significant in this equation. The coefficient of determination for Equation 1 was 19.3 percent.

The regression coefficients of the four protective devices were remarkably similar. It might be inferred from this fact that hazard was relatively independent of the type of protective device. To ascertain the statistical significance of the coefficients for the protection variables, a second multiple regression equation was developed which excluded the four types of crossing protection and included the remaining variables. The coefficient of determination for Equation 2, presented below, was 18.3 percent.

$$2. \quad IH = 0.185 + 0.079X_{40} + 0.021X_{41} + 0.011X_{54} + 0.013X_{55} + 0.024X_{57}$$

where IH = index of hazard,

X_{40} = number of track pairs,

X_{41} = pavement width in feet,

X_{54} = TPD,

X_{55} = ADT/1000, and

X_{57} = sum of distractions.

An F-test was performed on the multiple coefficients of determination for Equations 1 and 2 to test the hypothesis that the regression coefficients for the four protective devices as presented in Equation 2 were not significantly different from zero. This hypothesis was not rejected at the 5-percent level of significance.

This analysis did not show that protection devices had a significant influence on the prediction of hazard at grade crossings. Although the protection device variables can be eliminated from the prediction equation, the result of this significance test does not warrant the conclusion that protection devices have no influence on reducing hazard. This finding

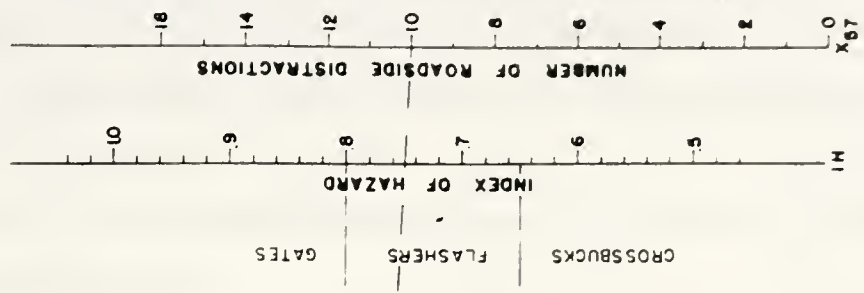
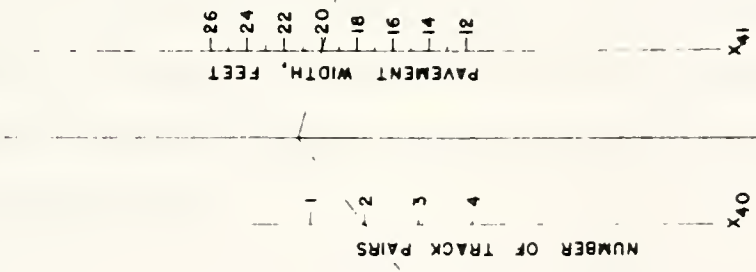
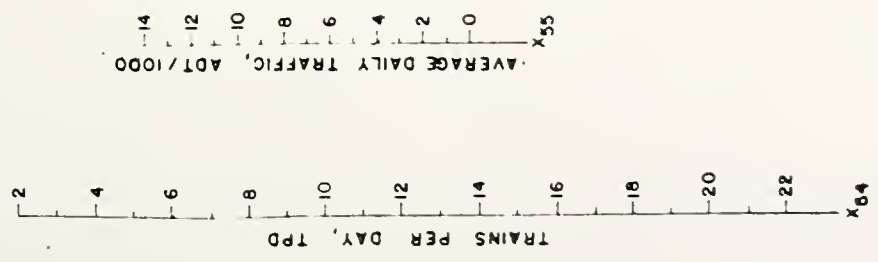
is restricted by the limited variability of the field conditions for the four types of protection investigated. As an example, all high-volume roads were generally protected with flashers or gates, and all low-volume roads were protected primarily with crossbucks. Perhaps a before-and-after study at locations where changes in protection devices are made is necessary for such evaluation.

Because the inclusion of the protection variables did not materially improve the estimation of hazard and because the types of protection device were equally weighted, the nomograph shown as Figure 1 was developed from Equation 2. In an attempt to correlate the index of hazard with the present standards of installing protection devices at grade crossings in Indiana, the mean indices of hazard were calculated for the study crossings protected with reflectorized crossbucks, flashers, and gates. These mean values were, respectively, 0.523, 0.774, and 0.823. A suggested warrant for the selection of at-grade protection was determined by computing the average value between the mean index of hazard for the various protection devices. Flashers would be warranted if the index of hazard is greater than 0.65, and gates would be recommended for indices greater than 0.80. The values suggested for these warrants are based on current levels of protection. Painted crossbucks were not included in the nomograph because all crossbucks are required to be reflectorized by State law. Although many painted crossbucks are presently in service, these devices are to be replaced with reflectorized crossbucks when necessary.

$$IH = -0.185 + 0.079X_{40} + 0.021X_{41} + 0.011X_{54} + 0.013X_{55} + 0.024X_{57}$$

EXAMPLE

- $X_{54} = 6$
- $X_{55} = 4$
- $X_{40} = 2$
- $X_{41} = 20$
- $X_{57} = 10$
- $IH = 0.75$



HOUSES, BUSINESSES, AND ADVERTISING SIGNS PER ONE-HALF MILE, BOTH SIDES OF ROADWAY, FOR ONE APPROACH TO THE CROSSING

FIGURE 1. PROTECTION NOMOGRAPH

The index of hazard and minimum protection warranted for the example shown on Figure 1 is determined in the following manner;

Given: $T2D = 6$; $ADT = 4000$; 2 track pairs; 20-ft pavement width; and 10 roadside distractions.

1. Draw a line extending from 6 trains per day through $4/1000$ ADT to turning line A.
2. From the intersection point on line A, a line is drawn through 2 track pairs and extended to turning line B.
3. From this point of intersection, a line is drawn through 20-ft pavement width and extended until it intersects turning line C.
4. After connecting this point on line C to the 10 roadside distractions, the index of hazard and minimum type of protection warranted is found at the intersection of this line with the index of hazard scale.

CONCLUSIONS

The following conclusions concerning hazard at railroad-highway grade crossings summarize the findings of this research investigation. As actual accident locations were compared to a random sample of non-accident locations, these results can reasonably be applied to all rural grade crossings within the State of Indiana.

1. The accident victims are predominantly young male drivers residing in the county in which the accident occurred. They are usually traveling alone and not under the influence of alcohol. More than one half of them are injured, and about one out of seven are killed.
2. Trucks account for more than one quarter of the accident vehicles. Seventeen percent of all vehicles involved in accidents have evidence of mechanical defects. The possibility of the driver hearing a warning bell or train whistle is reduced because the windows are closed on most vehicles. The majority of accidents occur at relatively low car speeds and at moderate train speeds.
3. Most accidents occur during the favorable driving conditions of clear weather, daylight hours, and dry pavements. However, the number of accidents per unit time and per unit exposure is probably greater for ice and snow conditions and for wet pavements than for dry pavement conditions.
4. The type of protection is not important as a variable in the equations developed by regression analysis for the prediction of index of hazard.

5. The regression equation developed by the multiple linear regression technique (Equation 2) identifies number of track pairs, highway pavement width, train volume, average daily traffic volume, and the sum of distractions (number of houses, businesses, and advertising signs) as important variables for the prediction of index of hazard. This equation explains 13 percent of the variation in accident occurrence.
6. Warrants for the installation of protective devices at rail-highway crossings, based on the current standard of protection used in Indiana, are hazard indices of below 0.65 for reflectorized crossbucks, 0.65 to 0.80 for flashers, and above 0.80 for gates.
7. This investigation of many roadway, railroad, traffic, and environmental variables permitted only an explanation of approximately 20 percent of accident occurrence. This finding lends support to the conclusion of many authors that railroad-highway grade crossing accidents are predominantly the result of driver characteristics and/or chance.

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